GM SPORT COMPACT PERFORMANCE BUILD BOOK

Part Number 88958728

THIRD EDITION

ECOTEC Race Engine Control Systems

Download more chapters at www.gmtunersource.com or see your local Chevy dealer to purchase a complete copy of this book

GM RACING

INTRODUCTION

GENERAL INFORMATION

This handbook describes parts and procedures used to prepare **ECO**TEC race engines used by GM Racing in professional Sport Compact Drag Racing and Drifting, as well as engine, transmission, and chassis modifications designed for sportsman-level drag racers.

This handbook is intended to be used by experienced and knowledgeable race engine and chassis builders. It does not cover all basic engine blueprinting and assembly procedures, since it is assumed that the reader is already familiar with machining, measuring, and inspecting the components. Some of the procedures described require specialized tools and skills. If you do not have the appropriate training and equipment to perform these modifications safely, this work should be performed by other professionals.

There are, of course, many other possible combinations of components and modifications that may produce equal or superior results. However, by using the combination of parts and procedures described in this handbook, an experienced engine builder can build a competitive and reliable **ECO**TEC Race Engine.

It is not the intent of this book to replace the comprehensive and detailed service practices explained in the GM service manuals. GM service manuals are available from:

Helm Incorporated www.helminc.com
PO Box 07130
Detroit, MI 48207

Observe all safety precautions and warnings in the service manuals. Wear eye protection and appropriate protective clothing. When working under or around the vehicle support it securely with jack stands. Use only the proper tools. Exercise extreme caution when working with flammable, corrosive, and hazardous liquids and materials.

PROGRAM HISTORY

The General Motors Sport Compact Drag Racing Program was kicked off at the 2001 International Auto Salon (IAS) in Long Beach, CA. During IAS, GM identified Sport Compact Drag Racing as the highest opportunity to gain awareness in the sport compact market. The first Chevrolet Cavalier and Pontiac Sunfire front-wheel-drive drag race cars were unveiled at the 2001 SEMA show, and, in February of 2002, GM Racing made their competitive debut in Palmdale, CA. In 2003 and 2004 the GM Racing team won back-to-back championships in both the NHRA Hot Rod and ProFWD categories. In 2005, GM transitioned from a factory race team to factory support of independant teams.

Fig. 1

Gary Gardella earned the 2005 NDRA Pro 4 cylinder championship in his first year running an **ECO**TEC race engine. 2006 and 2007 brought more championships, records, and wins for Chevy and **ECO**TEC.

WHY WE RACE

At GM, we race because it's where we came from and because it fuels our love for competition.

Racing has been part of the GM culture since auto pioneers like Louis Chevrolet relied on speed records and racing victories to launch his fledgling car company. GM has remained in racing for two basic reasons - to win on the track and win in the marketplace.

Racing is a compelling demonstration of the depth of GM's technical resources, the capabilities of its people and the performance, reliability, quality and safety of its products. The race track is the toughest of proving grounds to forge engineering, marketing and business skills into tangible results. Few, if any, environments can match racing's ability to build awareness and consideration of a manufacturer's products to new customers, while simultaneously solidifying the loyalty of current customers.

FIVE PILLARS GUIDE GM RACING'S INTEGRATED STRATEGY

It provides a **dynamic training ground** for GM engineers. In racing, decisions must be made at a rapid rate. You must be ready at all times, on time, and solve problems quickly and effectively. Racing's demands are the perfect venue in which to exercise the mind and expand abilities, improve teamwork and communication - and do it all without making excuses.

This leads to **technology transfer**. Racing is well known to have introduced improvements in the auto production industry in areas such as suspensions, brakes, engines, aerodynamics and safety - but there's also a transfer in technology through people who work in racing, then take those improved skills and knowledge to the production process. Likewise, the advanced technology and people involved in the mass production of vehicles has enhanced the development of race cars.

Human nature dictates that **people want to compete** - and win. There is a strong competitive spirit within GM, and success in racing produces a vibrant esprit de corps. GM is not a sponsor of racing - we are an active, engaged participant who produces the cars and the components, and provides the technology essential to the sport.

If racing did not already exist, auto manufacturers would invent it as the **perfect marketing platform**. Racing is a sport that's all about the product and the people, followed with cult-like passionate fans who buy cars and trucks at a higher and more loyal rate than the average consumer.

Grass roots racers and enthusiasts demand the best, and have made **GM Performance Parts** the leader in over the counter components and engine assemblies. GM's approach, as a participant in racing, is to take responsibility to support the sport. Someone else might even build a motor that beats the factory team. But it's this democratization of racing that sets GM apart, and is the cornerstone of GM's total business approach.

LEGAL INFORMATION

This publication is intended to provide technical information on the GM **ECO**TEC engines, Hydra-Matic transmission, and Chevy Cobalt used in sport compact drag racing at the professional and sportsman level.

This handbook pertains exclusively to engines and vehicles which are used off the public highways. Federal law restricts the removal or modification of any part of a federally required emission control system on motor vehicles. Further, many states have enacted laws which prohibit tampering with or modifying any required emission or noise control system. Vehicles which are not operated on public highways are generally exempt from most regulations, but the reader is strongly urged to check all applicable local and state laws.

Many of the parts described or listed in this handbook are merchandised for off-highway application only, and are tagged with the following "Special Parts Notice":

SPECIAL PARTS NOTICE
This part has been specifically designed for Off-Highway application *only*. Since the installation of this part may either impair your vehicle's emission control performance or be uncertified under current Motor Vehicle Safety Standards, it should not be installed in a vehicle used on any street or highway. Additionally, any such application could adversely affect the warranty coverage of such an on-street or highway vehicle.

The information contained in this handbook is subject to change. General Motors also reserves the right to make changes at any time, without notice, in equipment, manufacturers, specifications, and materials, or to discontinue items.

The information in this publication is presented without any warranty. *All the risk for its use is entirely assumed by the user*. Specific component design, mechanical procedures, and the qualifications of individual readers are beyond the control of the publisher, and therefore the publisher disclaims all liability incurred in connection with the use of information contained in this publication.

ORDERING PARTS IN THIS BOOK

Parts described in this book are from several sources. Many parts are available from aftermarket suppliers. The contact information for these suppliers is listed in a separate section of this book. Note that some parts may be available from additional sources.

There are three types of General Motors parts listed in this book. First are parts used in regular production vehicles. These are regular service and replacement parts, denoted as 'GM' parts in this book. These parts are available through any GM dealer. See www.gmgoodwrench.com for more information and to locate a dealer near you.

The second type of GM parts shown are GM Performance Parts. These parts are available only through authorized GM Performance Parts dealers. Not all GM dealers are authorized to sell GM Performance Parts. For more information or to locate an authorized dealer, visit www.gmperformanceparts.com. Please note that not all parts are listed on the GM Performance Parts website. Your authorized dealer has a more complete list. If your dealer is an authorized GM Performance Parts dealer and still cannot locate a GM Performance Part listed in this book, please e-mail GM Racing through our website www.gmtunersource.com.

The third type of parts listed in this book are available exclusively from GM Racing. These are typically low-volume parts for professional racing applications. All GM Racing Parts are for off-highway use only and are tagged with the ″Special Parts Notice″ shown previously in this book. GM Racing Parts are available only by e-mailing us through our website www.gmtunersource.com. Racing personnel will respond to you with additional ordering information and part availability. Please allow up to twelve weeks for delivery.

All part numbers are subject to change. Please contact the appropriate source for the most recent information.

BASE ENGINE OVERVIEW

The engine is the heart of a competition car. It must be capable of delivering full power reliably run-after-run on race day, at engine and vehicle speeds far in excess of those encountered in normal driving. Every part of a competition engine must be as nearly perfect as possible – the slightest failure can put you out of the race.

Since 1955, the Small Block Chevy has proven its versatility, durability, and performance potential with automotive performance enthusiasts. The **ECO**TEC engine has all the basic mechanical components to repeat this success. A sound base engine structure, excellent airflow capability, easy serviceability, compact size and low weight. These qualities, along with the very successful race program, demonstrate the **ECO**TEC engine is a driving force in the sport compact segment. (Fig. 2)

Fig. 2

GM's **ECO**TEC engine has proven to be a reliable and competitive engine for use in Sport Compact Drag Racing. It has also proven it's superior durability in grueling five mile runs at the Bonneville Salt Flats with speeds over 300 MPH and in showroom stock endurance road racing competition. The number of stock components utilized in the race engine demonstrates the robust design of the **ECO**TEC engine.

The **ECO**TEC's outstanding feature to performance enthusiasts is it's impressive strength. GM Racing dynamometer tests confirm that major horsepower gains are possible with minimal modifications. For instance, when building an **ECO**TEC engine to the 400 hp power level, no modifications to the cylinder head, block, main girdle or crankshaft are required.

The production **ECO**TEC engine block is manufactured out of aluminum using a lost-foam casting process. This process allows for both a stronger and lighter part. Flanged, thin-wall iron cylinder sleeves are press-fit into a semi-floating aluminum support structure. The **ECO**TEC block is supported by a massive die-cast aluminum girdle/main cap assembly and structural oil pan for noise and vibration suppression. The main-cap structures are each supported with six fasteners. Extra-thick main bearings resist the differential thermal expansion of the nodular iron crank and aluminum block.

All **ECO**TEC blocks are cast with passages for piston-cooling jets and an oil cooler for high-output turbocharged applications. The fully-boxed block requires no windage tray, even on applications up to 600 horsepower. An auxiliary chain drives the water pump and balance shafts from the crank.

To reduce the risk of hot spots, pressure-cast, non-squish dished pistons are manufactured without valve reliefs. The symmetrical, barrel-faced moly-coated top ring fits in an

anodized ring-groove below a super-thin 3 mm top ring land, creating a low crevice volume for reduced emissions. The pistons deliver power through full-floating piston pins and powder-metal or forged steel connecting rods.

The **ECO**TEC twin-cam cylinder head uses low-friction hydraulic roller finger-followers, which have been proven reliable and effective up to 11,000 rpm. Head fastener placement permits cylinder head removal and installation without removing the camshafts. The camshafts are driven directly off the crank by a chain. The design includes provisions for variable cam phasing now found on select **ECO**TEC variants. The finger-follower design permits a light-weight narrow profile and reduced valve angles(the intake valve is 18 degrees from vertical and the exhaust valve 16 degrees).

The design of the intake manifold eliminates the need for variable-length intake runners and some **ECO**TEC engines now include direct injection.

The **ECO**TEC engine management system uses a port-EFI design with cassette waste-spark ignition.

The next several sections of this publication focus on performance modifications for the 2.2L **ECO**TEC engine installed in a 2005 Chevy Cobalt. The modifications shown could be performed on a number of GM vehicles.

See your local GM dealer for more information on ordering a vehicle equipped with the **ECO**TEC engine.

ECOTEC ENGINE CODES

Engine Code	Usage	Displacement	Bore x Stroke	CR:1	Fuel	Induction	Hp @ rpm	Tq @ rpm
L61	Saturn ION & VUE Chevy Malibu, Cobalt & HHR Pontiac G5	2.2L	86 x 94.6 mm	10	SFI	Naturally aspirated	148 @ 5600	152 @ 4200
LE5	Saturn ION & Sky Chevy Cobalt Sport & HHR Pontiac G5 GT, G6, & Solstice	2.4L	86 x 98 mm	10.4	SFI	Naturally aspirated with VVT	173 @ 6200	163 @ 4800
LSJ	Saturn ION Redline Chevy Cobalt SS S/C	2.0L	86 x 86 mm	9.5	SFI	Supercharged	205 @ 5600	200 @ 4400
LNF	Pontiac Solstice GXP Saturn Sky Redline Chevy HHR SS & Cobalt SS	2.0L	86 x 86 mm	9.2	DI	Turbocharged with VVT	260 @ 5300	260 @ 2500
LK9	Saab 9-3	2.0L	86 x 86 mm	9.5	MPFI	Turbocharged	210 @ 5300	221 @ 2500
LAT	Saturn Aura Green Line	2.4L	86 x 98 mm	10.4	SFI	Naturally aspirated hybrid	164 @ 6400	159 @ 5000

ECOTEC RACE ENGINE CONTROL SYSTEMS

ENGINE METRICS

The Air Fuel ratio is dependant on the type of fuel, the type of sensor, and what system is reading it. Below are the generally suggested air-fuel ratios and, more importantly, the suggested EGT range used by GM Racing on the GM ECOtec turbocharged race engines. Note that the amount of spark lead has a major influence on the exhaust temperature.

In gas race engines, GM highly recommends Torco 118 over C16 race gas. E85 is another good fuel choice at the sportsman-level, as it helps to keep engine temperatures down.

Fuel	AFR	EGTS
C-16 Fuel	10.2 to 10.8	1500 to 1600 max
Torco 118	10.8 to 11.4	1300 to 1550 max
E-85	7.1 to 7.3	1200 to 1400 max
Methanol	3.75 to 4.3	1180 to 1300 max

On the naturally aspirated ECOtec race engine, which runs on E85, we have AFR of 8.9 to 9.2 with EGT readings in the 1200 to 1380 degrees F range.

In boosted **ECO**TEC race engines, a maximum of 14 degrees of spark timing is recommended to start performance testing.

FUEL INJECTORS

Fig. 113

Injector applications are as follows: (Fig. 113)

Horsepower	Fuel	Number of Injectors	Injector Flow Rate
400 to 600	Gas	4	70 lbs. per hour RC high impedance
400 to 600	Methanol	4	160 lbs. per hour
400 to 600	E85	4	160 lbs. per hour
600 to 900	Gas	8	83 lbs. per hour
600 to 1250	Methanol	8	160 lbs. per hour
1250 and up	Methanol	12	160 lbs. per hour

Here is the basic process we use for determining injector sizing.

1. Calculate the base injector size.

(Desired Engine Power @ Flywheel x BSFC) / # of cylinders = required injector size in lbs/hr

For BSFC (Brake Specific Fuel Consumption) use:
Naturally aspirated engines-0.4-0.5
Supercharged or Turbocharged engines-0.5-0.6

Note: This assumes 1 injector per cylinder and a fuel pressure of 43.5 psi with gasoline as a fuel.

For example, here is the calculation for a turbo-charged 400 hp I4 engine:
(400 x 0.6)/4 = 60 lbs/hr

Note: When using a fuel other than gasoline, adjust your fuel requirement by the percentage difference between the gasoline stoiciometric fuel ratio and that of the fuel you wish to use. For example, the difference between gasoline (14.7:1) and E85 (9.76:1) is 50%. Therefore, instead of 60 lbs/hr, you would calculate 90 lbs/hr for E85.

2. Adjust for percent duty cycle.

The base calculation above assumes 100% duty cycle of the injector, which is not realistic. We recommend a maximum of 80% duty cycle. Divide by 0.8

60 lbs/hr / 0.8 = 75 lbs/hr

3. Know your engine management system.

Find out if your engine management system requires ″Peak and Hold″ or ″Saturated″ style injectors. The Peak and Hold injectors are low resistance (2.5-3 ohms) and the Saturated injectors are high resistance (12-16 ohms). Most aftermarket engine controllers prefer the Peak and Hold, but some will run either.

4. Choose your injectors.

For our example, the two closest size injectors available are 72 lb/hr and 83 lb/hr.

FUEL PUMP

Here is the basic calculation we use for determining required fuel pump flow.

1. Calculate the base fuel pump flow.

Flow in gal/hr = HP * BSFC *(1 / fuel weight)

For BSFC (Brake Specific Fuel Consumption) rated in lbs. per horsepower-hour, use:
0.45 to 0.5 for naturally aspirated engines
0.55 to 0.60 for supercharged engines
0.60 to 0.65 for turbocharged engines

For fuel weight, use
6.216 lb/gal for regular unleaded
6.350 lb/gal for premium unleaded

For example, here is the calculation for a turbo-charged 400 hp I4 engine on premium unleaded gasoline.
400 * 0.60 * (1/6.350) = 38 GPH

2. Include a factor of safety.

We recommend a 30% increase for safety, which is the generally accepted amount for fuel pump sizing. Multiply by 1.3.

38 GPH * 1.3 = 49 GPH

3. Choose your fuel pump.

Choose a fuel pump that has the calculated flow at minimum output. Methanol fuel requires about twice the flow of gasoline.

Fig. 114

An Aeromotive or Weldon boost compensated fuel pressure regulator is used by GM Racing. (Fig. 114)

As boost rises, the fuel injector needs more pressure to overcome the increasing pressure in the intake manifold and spray the proper amount of fuel. The special regulator has a boost pressure sensing line which allows the regulator to increase fuel pressure by one pound for every

pound of boost. This keeps differential pressure constant across the injector. (Fig. 114)

Fig. 115

Cobalt Phase5 (500 hp): Aeromotive A1000 high pressure fuel pump part number 11101 (Fig. 115)

The stock fuel line bundle can be used for fuel supply and return. Adapting AN fittings to the factory lines is the preferred method. (Fig. 115)

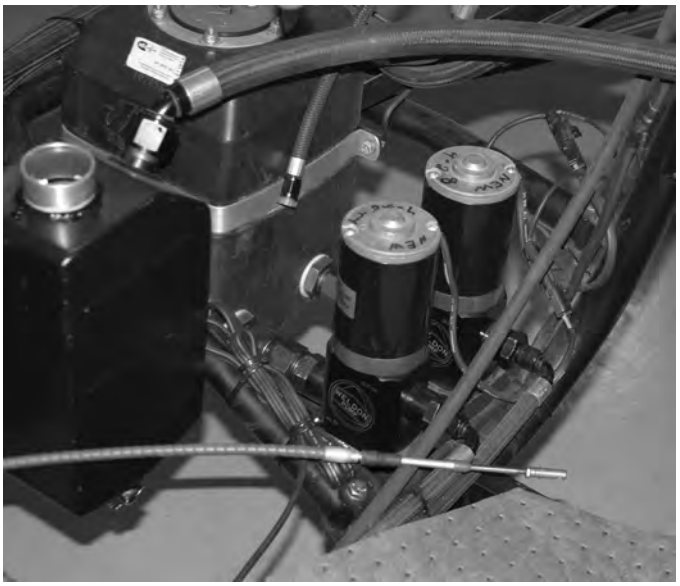

Fig. 116

Turbo Street (800 hp) and Drift (500 hp): One Weldon 2345A high flow, high pressure fuel pump with Weldon 1021 fuel pressure regulator. Recommended base fuel pressure is 45 psi static.

Hot Rod (1200 hp): Two Weldon 2345A high flow, high pressure fuel pumps with Weldon 1021 fuel pressure regulator. Recommended base fuel pressure is 70-75 psi static. (Fig. 116)

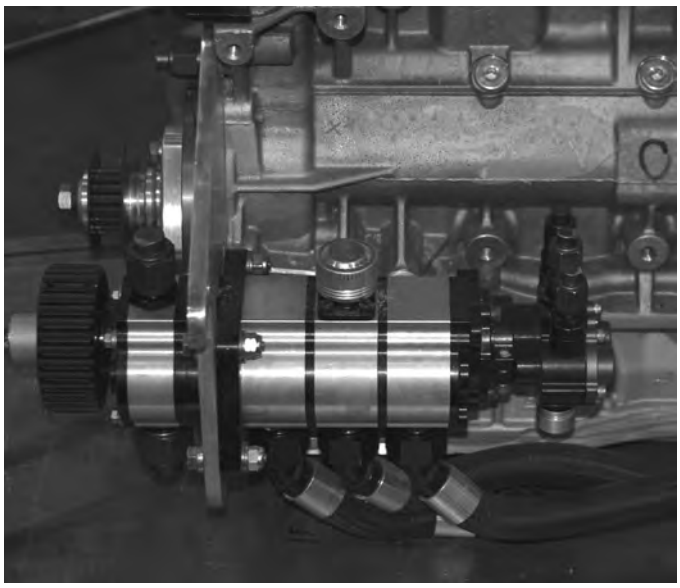

Fig. 117

Pro (1400 hp): DSR –1 mechanical fuel pump driven off of dry sump oil pump with Weldon 1021 fuel pressure regulator. Recommended base fuel pressure is 70-75 psi static. (Fig. 117)

Caution:
Utmost care must be taken with the fuel system components when using Methanol fuel. The fuel system must be flushed with a gasoline type fuel after use.

ENGINE MANAGEMENT

Fig. 118

GM Racing uses and recommends F.A.S.T. XFI engine controllers in all professional-level **ECO**TEC-powered race cars (Fig. 118). GM Racing has several F.A.S.T. XFI base

calibrations for ECOtec race engines, which are available on a case-by-case basis. Custom wiring harnesses for use with this system are available from Roush Industries.

At the sportsman level, F.A.S.T. XFI and MEFI controllers have been used in applications where the production controller and wiring harness are removed. Note that these application also involve an after-market dash and mechanical throttle.

For production-based applications (typically below 325hp), 'piggy-back' controllers or a production controller re-flash may be included with aftermarket power-adder kits. The GM Performance Parts Stage Three kit for the 2.0L LSJ engine in the Cobalt SS Supercharged includes a re-flashed controller. Additionally, HPtuners offers aftermarket software that is capable of tuning select **ECO**TEC production controllers.

IGNITION SYSTEMS

Fig. 119

A distributor system is currently used on all professional-level drag race **ECO**TEC engines. It includes:

- MSD 75314 Programmable Digital 7
- MSD 8261 Pro Power HVC II Coil
- MSD 8498 **ECO**TEC Distributor
- MSD 32769 8.5mm spark plug wire kit

For applications under 40psi of boost, an MSD 8251 Pro Power HVC Coil is used instead of MSD 8261.

GM Racing modifies the MSD distributors used on professional-level **ECO**TEC drag race engines (Fig. 119). The rotor-holder included with the distributor is either re-welded or replaced with a billet rotor-holder made by GM Racing. Green wicking Loctite is used between the rotor-holder and shaft. Red Loctite is used on the two rotor-holder allen bolts. Lock-nuts are added and/or blue Loctite is used on the two rotor screws. These screws are double-checked before every run.

A mini-blaster coil system is currently used on Drift and naturally aspirated **ECO**TEC race engines. This system includes:

- MSD 62153 DIS 4 Plus
- MSD 8207 Blaster SS coils (Qty 4)

TURBOCHARGER

Fig. 120

The following list shows recommended baseline turbos for a given power level. Check with your preferred turbo dealer for specific turbo recommendations. Borg Warner AirWerks turbo is shown in Fig. 120.

400-600hp

Borg Warner AirWerks S200 (part number 317222)
Garrett GT 35R
Turbonetics T3/T4 Hybrid

600-1000hp

Borg Warner AirWerks S400SX, 71mm
(part number 177248)
Borg Warner AirWerks S400SX, 74mm
(part number 177101)
Garrett GT 40R

1000-1200hp

Borg Warner AirWerks S510 (part number 174289)
Garrett GT 42R

1200-1500hp

Borg Warner AirWerks S510 (part number 174289)
Garrett GT 45R

BOOST CONTROLLER

Fig. 121

Innovative and MSD offer boost controllers specifically designed for drag racing. The Innovative controller changes boost and boost ramp rate based on which gear the transmission is in. The MSD system is based on time from vehicle launch has a tuneable PID controller and a user-defined boost curve. Because of its greater tuneability, GM Racing uses the MSD boost controller in professional-level drag race cars. (Fig. 121)

Both systems output a P.W.M. signal that controls a solenoid to vary pressure on the top of the waste gate. This pressure change opens and closes the waste gate to vary engine boost as required.

Be sure you have sufficient pressure on top of the waste gate to ensure that the waste gate will stay closed when high exhaust pressure is present.

In drifting, GM Racing uses a mechanical HKS waste gate with a 20-22 lb. spring. We found this set-up to be best with varying throttle input.

WASTE GATES

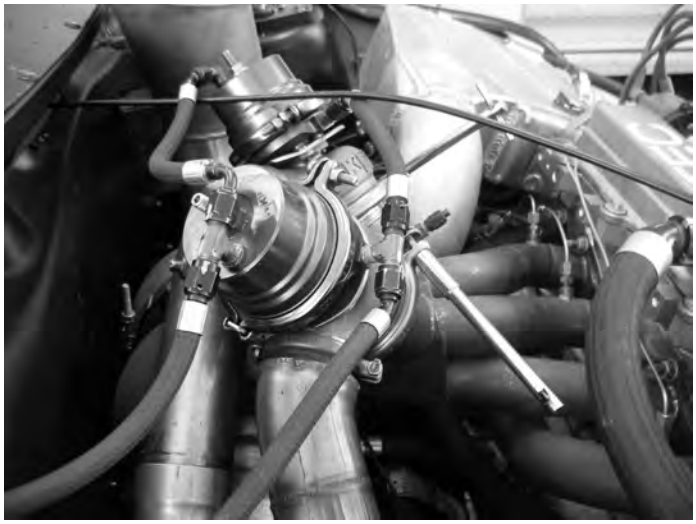

Fig. 122

ECOTEC racing engines use the following waste gates:

- Tial 42 mm (below 900 hp)
- HKS 60 mm GTII

In front wheel drive drag racing boost control is critical. The waste gate(s) should be sized to enable the boost controller to reduce boost to a level low enough to control wheel spin in the lower gears.

In applications using an aggressive two-step rev limiter (such as professional-level drag racing), GM Racing uses the HKS 60 mm GTII gates with modifications to the valve guide and seal. These modifications are made by Roush Industries and are required for reliability.

In applications reaching 60 psi of boost, it may be necessary to utilize two waste gates. These gates should be plumbed in parallel.

For drifting, GM Racing uses a single 40-42 mm waste gate.

INTERCOOLER

Fig. 123

Air-to-air and air-to-water intercoolers reduce the inlet charge temperature to improve performance and reduce spark knock sensitivity. (Fig. 123) An intercooler core from Precision Turbo is used in a air-to-water system on GM Racing professional level **ECO**TEC drag cars.

Fig. 124

Intercooler circulating pump (Fig. 124)

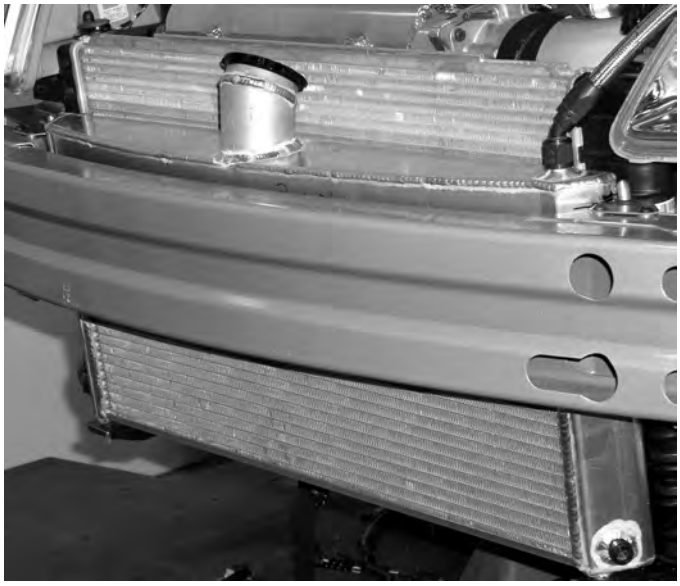

Fig. 125

Fig. 125 shows a sportsman application using an air-to-water intercooler.